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Dielectric properties and ac conductivities of $Bi_{1-x}Sm_xFeO_3$ ceramics

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Multiferroics attract much attention of researchers due to simultaneous coexistence of ferroelectric and magnetic properties in one phase. One of the most promising multiferroics is $BiFeO_3$. A great interest in this material is due to the high temperatures of the antiferromagnetic (T_N = 370 ºC) and ferroelectric ordering T_C = 830 ºC [1,2]. The unique properties of BFO and materials based on it open wide prospects for use in various magnetoelectric devices, spintronics, sensor technology, magnetic memory. However, the functionality of BFO is limited by the presence of impurity phases and various kinds of structure defects that arise when it is produced and generate dielectric losses and high leakage currents. Low resistivity as well as high leakage current worsens its ferroelectric properties. Most authors attribute a deterioration in the electrical properties of BFO to non-stoichiometric oxygen deficiency [3,4], as well as the presence of concomitant phases [5].

In this work, we studied the structure, frequency and temperature dependences dielectric properties and ac conductivities of $Bi_{1-x}Sm_xFeO_3$ (x = 0, 0.5, 0.1, 0.15, 0.20) ceramics. BSFO ceramics were obtained by cold pressing of nanopowders thermally treated at 600°C. Analysis shown that BSFO-5 as well as BFO crystallizes in rhombohedral structure with R3c space group. XRD analysis of the composition BSFO-10 indicates the presence of a new orthorhombic (space group: Pbam) phase. With a 15% bismuth's substitution, the crystal structure is completely transformed from rhombohedral to orthorhombic phase.

The measurements dielectric constant (ε) and ac conductivity (σ_{ac}) were carried out in the frequency range 1 kHz – 10 MHz in the temperature range 25-600 °C. Both components of ε undergo strong frequency dispersion. The intense temperature growth of the real part ε' begins above 200 °C, reaches its a local maximum at ~ 230 °C, and has a frequency-dependent character inherent to relaxors. Its maximum value $\varepsilon'(T)$ reaches at ~ 300 °C (Fig. 1). We note that the dependences of $\varepsilon'(T)$ for all the samples studied are on the whole identical. However, there are some differences. Thus, the anomaly in the region ~ 240 °C is clearly evident in compositions with a higher samarium concentration (BSFO15, BSFO20). Moreover, the maximum of the values of $\varepsilon'(T)$ for these compounds differs by almost an order of magnitude from the initial composition of the BFO. At room temperature and at a frequency of 1 kHz, ε' increases from 80 (x = 0) to 150 (x = 0.2).

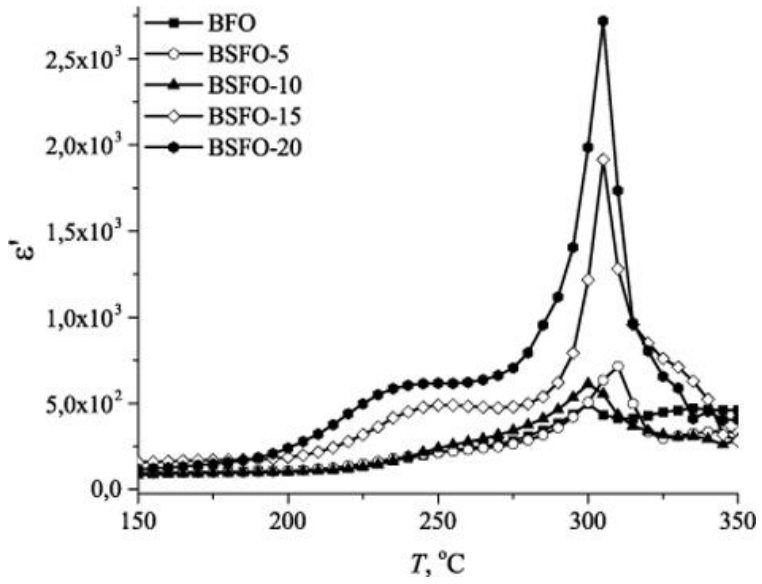

Figure 1. Thermal dependence ε′(T) at 1kHz for $Bi_{1-x}Sm_xFeO_3$

Figure 2 shows the different conductivity character in different temperature and frequency ranges. At low frequencies and temperatures above 300 °C the conductivity of all BSFO compositions gradually increases up to 600 °C. Conductivity is higher for samples with a high samarium concentration. As can be seen from Fig. 2 (insert), the dependence $\sigma_{ac}(T)$ for 10 MHz reaches to saturation and passes through a maximum. Moreover, the maximum conduction temperature is shifted to lower temperatures area with an increase in both the frequency and the percentage content of samarium.

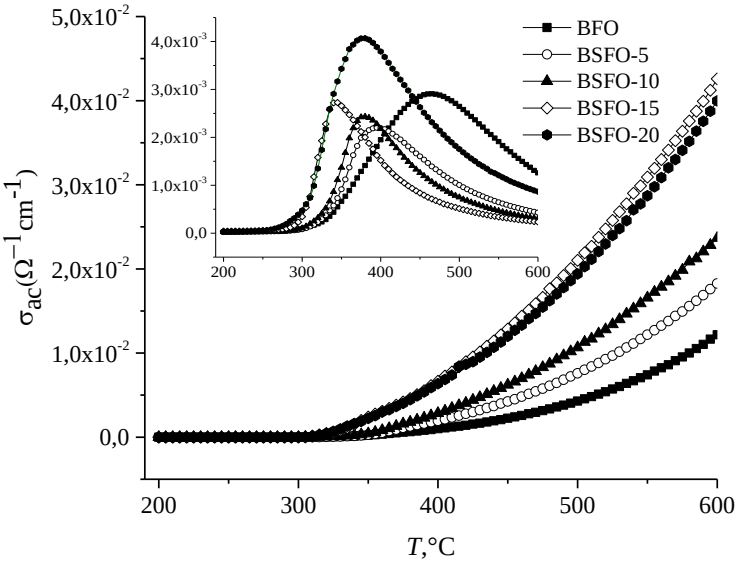

Figure 2. Thermal dependence σ_{ac}(T) at 1kHz and 10 MHz (insert) for $Bi_{1-x}Sm_xFeO_3$

The low-frequency conductivity is identified with the dc conductivity (σ_{dc}). At frequencies > 100 kHz conductivity behavior can be interpreted in frame of the model of correlated barrier hopping (CBH) of charge carriers [6].

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